EXHIBIT C:

Selection of Receivers for FM Receiver Testing and Analysis of Test Results

MLJ MOFFET, LARSON & JOHNSON, INC.
CONSULTING TELECOMMUNICATIONS ENGINEERS

ENGINEERING REPORT

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Selection Of Receivers For FM Receiver Testing And Analysis Of Test Results In Support Of The Comments Of The National Association Of Broadcasters In MM Docket No. 99-25

July 21, 1999

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National Association of Broadcasters
Washington, DC

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Introduction

MLJ, Inc. has been retained by the National Association of Broadcasters (NAB) to conduct engineering studies in support of the NAB comments in MM Docket No. 99-25. In this proceeding the FCC proposes to create a low power FM broadcasting service (LPFM). NAB has sponsored the measurement program to determine the interference susceptibility of contemporary FM broadcasting receivers. The purpose of this study is to analyze the results of the measurements and to relate the results to the Commission's proposals in MM Docket No. 99-25. In addition, the selection of the FM receivers used in the tests is reviewed.

Selection of Receivers

This section of the report presents a review of the selection of receivers for testing in the NAB's program. Appendix A lists the make, model and a brief description of the receivers tested in the NAB measurement program by the type of receiver. Receiver types are considered to consist of five categories. Distinguishing features of the receivers, such as the type of antenna employed, are given. The categories are:

1) Automobile - Both Original Equipment Manufacturer (OEM) and "after-market" radios are included and are listed separately.
2) Clock/table radios - These receivers normally have line cord antennas.

3) Component - Tuners or receivers with provision for external antennas and other audio sources such as tape and compact discs.
4) Personal portables - Headphone receivers, generally with no external antenna (*e.g.* "Sony Walkmans").
5) Portables - Carryable receivers generally with integral "whip" antennas for FM (*e.g.* "boomboxes").

As can be seen in Appendix A, the makes are popular brands that are in national distribution. The receivers were all purchased at retail stores except for the OEM car radios. No testing of the radios was made prior to selection and inclusion in the program. No sales data is available on the particular models; such data is generally considered proprietary by the manufacturers. However, the primary criterion was the ready availability of these models and the judgment that typical receivers were chosen and not those limited in production and availability. Limited sales data are available and are discussed later in the report, however there is no known data on actual listening for a particular receiver or even type of receiver. For example, persons may have a number of clock radios that are basically used as alarm clocks and are used very little for actual listening, whereas another person may use a clock radio for extensive listening at a workplace. Rating services that monitor listening do not record actual receiver types. Thus, it does not appear possible to weight the measurement data on receiver performance to represent actual listening.

Twenty-eight receivers were tested; five of each category were included except automobile where eight were tested.[1] The data is presented in terms of the median of all receivers. Considering the multitude of receivers tested and the use of the median, the interference performance of any one receiver, whether particularly good or poor, has negligible effect on the median. As might be expected, there was considerable variation among the receivers tested. There was also significant variation among receivers of a given type. To demonstrate this, measured desired to undesired ratios (D/U)[2] are shown in Table 1 for second adjacent channel interference for each category. The ratios are for the data for a desired input of -55 dBm. This desired input power is the central level used in the tests; tests were made for values of -45 dBm, -55 dBm and -65 dBm.

Table 1
Measured Second Adjacent Desired to Undesired Ratios (dB)
Desired Input = -55 dBm

Receiver Type	Median					Difference Median & Worst	Difference Median & Best
Clock	-12.4	-15.1	-16.7	-17.6	-32.6	4.3	15.9
Walkman	-5.5	-15.3	-25.6	-27.4	-30.8	20.1	5.2
Portable	-4.2	-9.0	-16.6	-20.7	-21.7	12.4	5.3
Component	-15.5	-25.6	-31.4	-31.8	-45.8	15.9	14.4
Auto After Mrkt	-15.5	-17.2	-27.7	-61.0	-64.7	11.5	37.0
Auto OEM		-41.9	-45.1	-61.5		3.2	16.4

[1] Five "after-market" and three OEM automobile receivers were tested. The OEM models were from Chrysler, Ford and General Motors vehicles.

[2] The interference criteria are when interference caused a degradation of 5 dB in S/N or to a S/N of 50 dB when receiver S/N exceeded 55 dB.

Although the sample size is small when types of receivers are considered, some observations may be made to at least indicate the lack of bias in selection of receivers. Table 1 shows that often the performance of one or two receivers in each class is much better than the median for the class. For the personal receivers and the portables the median appears to be more representative of the better receivers. The component receivers show a wide range (over 30 dB) with the median in the center. Considering the foregoing, it appears highly unlikely that only, or predominately, "poor" receivers in each class were selected to bias the data.

Some may question the selection of automobile receivers because after-market receivers make up two thirds of the test auto receivers, but may make up a smaller portion of the actual population of receivers and listening in vehicles. However, the actual mix has very little impact on the median results. For example, the median second channel ratio at -55 dBm desired input signal is -23.7 dB for all receivers. Eliminating the after-market receivers changes the median to -21.7 dB, indicating that after-market automobile radios actually raise the median. If all after-market car receivers in the test are assumed to be equivalent to the OEM median (D/U = -45.1) (*i.e.*, if all eight auto receivers were equivalent to the median OEM receiver), there is relatively little effect on the median for all receivers; median performance only improves by 3.5 dB to -27.2 dB. Receiver sales data discussed later in this report indicate that after-market radios ultimately replace the majority of OEM radios.

Tests of television receiver interference susceptibility that support the instant test selection have been made in the past by the Commission,[3] ACATS[4] and TASO.[5] The receiver selection process for these tests may be compared to that employed here by NAB. The TV tests have been used in various engineering studies and the development of FCC rules. In particular, receiver tests form the basis for the Low Power Television (LPTV) rules, Non-commercial/ Educational FM interference to TV Channel 6 rules, and the relatively recent (DTV) interference rules. In all cases simple, unweighted medians of receivers were used. Generally, selection of receivers was similar to that employed by NAB, that is, the judgment that receivers were typical and generally available. There was then, as now, no basis for selecting a scientific sample of receivers because receiver penetration by model is not known nor is the listening pattern.

Receiver Sales Data for NAB Receiver Categories

Receiver sales data is available for 1998 retail sales[6] and 1997 automobile factory installations.[7] These data may be combined assuming that sales variations from one year to the next are not important when the results are rounded to a few significant figures. Table 2 shows receiver units for the five NAB categories except that after-market and OEM receivers are considered

[3] W. K. Roberts et al, " A Study of the Characteristics Of Typical Television Receivers Relative To The UHF Taboos", June 1974.
[4] Advisory Committee on Advanced Television Service (ACATS), Record of Test Results October, 1995.
[5] Television Allocations Study Organization (TASO), Final Report 1960.
[6] Consumer Electronics Manufacturers Association (CEMA) market research.
[7] CEMA "OEM Mobile Electronics Trends Guide" 1998.

separately. For the first case, after-market receiver sales are ignored because nearly all vehicles (more than 95%) are sold with OEM radios. In the second case after-market auto receivers are considered to replace OEM receivers, that is the total number of auto receivers remains constant.

Table 2

Category	Units (millions)	Percent - OEM Only	Percent - Constant Auto
Auto - OEM	16.4	20.5	8.8
Auto - After-market	9.4	-	11.8
Clock	12.4	15.6	15.6
Component	11.3	14.1	14.1
Personal Portable	17.7	22.2	22.2
Portable	21.9	27.5	27.5

As can be seen from Table 2, OEM auto receivers make up at most approximately one-fifth of receivers sold. The total percentage of the receivers most susceptible to interference (clock, personal and portable receivers) comprise more than three-fifths of receivers (65.3 percent). Thus, these types of receivers must be considered to adequately protect FM service from interference.

Review of Measured Results

The NAB FM receiver interference susceptibility tests were performed by the Carl T. Jones Corporation (Car T. Jones) and submitted to the Commission in this proceeding as a separate report in the NAB comments. The Carl T. Jones Report presents measured desired-to-undesired interference ratios (D/U) for the twenty eight receivers.[8] Measured ratios are included on the report for co-channel and first, second and third adjacent channel interference.

The test results show that interference susceptibility is dependent on the strength of the desired signal in some cases. Measurements were made with desired input signal powers of -65 dBm, -55 dBm and -45 dBm to represent a variety of receiving conditions. The lowest value (-65 dBm) represents reception at the FM 1 mV/m (60 dBu) contour approximately 1.5 meters above ground level (standing or mobile antenna height). For reception at the 60 dBu contour at the standard 9 meter antenna height the value of -55 dBm is appropriate.[9] A value of -45 dBm represents reception of signals 20 dB stronger than the first condition (80 dBu contour for antennas 1.5 meters high, 70 dBu contour for antennas 9 meters high).

Receivers vary substantially in their ability to reject interference. Thus, a representative number of receivers (twenty-eight) were tested. As described above, to facilitate the analysis receivers were grouped by type or category. In the Carl T. Jones Report the results are presented in terms of the minimum, maximum and median D/U of all receivers. The measured ratios for individual receivers are also shown in graphical form in the Carl T. Jones Report. The graphs show anomalies for some receivers where the trend of the measured ratios appears

[8] Carl T. Jones Corporation, *FM Receiver Interference Test Results Report*, July 1999 ("Carl T. Jones Report"), pp. 23-25.
[9] The FCC assumes an antenna height of 9 meters above ground as a basis for its FM field strength predictions.

to reverse for different desired signal powers. These anomalies would appear as discontinuities if the measured ratios were plotted as a function of desired signal strength. They are likely caused by processes within a receiver. For example, receivers may switch or blend from mono to stereo as a function of signal power or baseband noise. This lessens perceptible (and measured) interference because monaural reception is inherently less susceptible to noise and interference than stereo. Some receivers may reduce bandwidth in an attempt to reduce interference. Because of the discontinuities that appear on some graphs, data for individual receivers should generally not be used. The use of median values, particularly when relatively large numbers of receivers are considered, tends to overcome this problem. However, because the data are median values, it should be noted that half the test receiver population would not be adequately protected from interference by protection ratios based on the median values.

Comparison of Measured Data With Present FM Allocation Standards

The Commission has proposed that it may be necessary to abandon the second and third adjacent channel interference protection of FM stations from LPFM stations so that larger numbers of LPFM stations may be "dropped in." The Commission's justification is that receivers have allegedly improved over the years since the FM interference standards were adopted.[10] To test this hypothesis, measured interference ratios may be compared with standard ratios used in the rules. The focus is on the second and third adjacent channel ratios. Data for the median receiver is used in the comparison. The median is generally used in the broadcasting services for interference susceptibility. Because receivers vary substantially in performance, actual interference is generally more widespread than indicated by an area based upon predictions using a median ratio.

Measured Second Adjacent Channel Interference Ratios

The Commission's second-adjacent channel ratios differ between the reserved non-commercial educational band (N/CE) and the non-reserved band. Table 3 shows measured median second-adjacent channel ratios in dB compared with the ratios of the Commission's rules.

Table 3

Second Adjacent Channel Interference Ratios (dB)

		Received Power		
FCC Reserved	FCC Non-reserved	-65 dBm	-55 dBm	-45 dBm
-20	-40	-30.5	-23.7	-17.0

Table 3 indicates that there is no basis for concluding that receivers have improved sufficiently so that the second adjacent channel interference protection can be abandoned. Indeed, the data show that the non-reserved value of -40 dB is inadequate to protect FM reception. The table also shows that interference rejection capability of receivers tends to decline as desired signal strength increases.

[10] In the Matter of Creation of a Low Power Radio Service, MM Docket No. 99-25, adopted January 28, 1999 at 42 and footnote 57.

Measured Third Adjacent Channel Interference Ratios

Table 4 shows measured median third adjacent channel ratios compared with the ratio of the Commission's rules.

Table 4

Third Adjacent Channel Interference Ratios (dB)

	Received Power		
FCC	- 65 dBm	- 55 dBm	-45 dBm
-40	-39.7	-32.0	-26.8

As with second adjacent channel interference, the above table also shows that the interference rejection capability of receivers tends to decline as desired signal strength increases. The data show that the present FCC third-adjacent channel protection ratio is approximately valid for the -65 dBm reception condition but is not adequate for protection of reception at higher received powers that occur within protected contours.

D/U Versus Received Power

The increase in interference susceptibility as a function of received power is illustrated in Figures 1 and 2 in Appendix B. These are graphs of median measured D/U as a function of desired received power for both second and third adjacent channel interference. The graphs show that the change is essentially linear over the 20 dB desired signal range that was used in the tests. The linear regression equations are:

For second adjacent channel interference

$$D/U = 0.675P + 13.4 \quad (dB)$$

For third adjacent channel interference

$$D/U = 0.645P + 2.5 \quad (dB)$$

Where P is the received power in dBm.

In interference studies, a constant ratio equal to that at the 60 dBu contour is usually assumed. The equations show that this is generally not a valid assumption. The slope of the lines is approximately 0.7 dB, that is, for every 1 dB increase in desired signal, most of that increase, or nearly 0.7 dB, is lost because of declining receiver interference rejection performance. Applying these equations to stronger desired signals than those reported in the Carl T. Jones Report should be done with caution. For signals stronger than the highest tested (-45 dBm), the slope could increase to equal or exceed unity which would imply increasing interference. Constant ratios, usually the ratios appropriate for protecting the 60 dBu contour, are often used to predict interference. If a constant ratio were appropriate for all desired signal levels, the slope would be low, that is, essentially zero.

This effect can also be seen by calculating the predicted radius of second-adjacent channel interference at the 60 dBu and 80 dBu contours, by assuming 60 dBu is equivalent to received power of -65 dBm and 80 dBu is equivalent to -45 dBm. The results may be compared to the value calculated by assuming that the -65 dBm received power ratio is also valid at the 80 dBu contour, in other words the ratio would be virtually constant throughout a station's service area. For the example of 1000-watt LPFM stations, at the 60 dBu contour the predicted radius is 2.48 kilometers and is reduced to 1.71 kilometers at the 80 dBu contour using the -45 dBm data. Using the -65 dBm ratio at the 80 dBu contour the predicted radius of interference is only 0.29 kilometers.[11] Thus, the measured data show that the interference radius would only be reduced to approximately 70% at the 80 dBu contour compared to that of the 60 dBu, not to less than 12% as would result by using a constant interference ratio. The area of interference is proportional to the square of the radius. Use of a constant ratio would lead to the erroneous conclusion that at the 80 dBu contour the area of interference is only about 1.4% of the area at the 60 dBu contour. As the above calculations are based upon the "median receiver;" in some receivers there would be little on no decrease in the area of interference as desired signal is increased. For a full-facility Class B FM station, the distance to the predicted 80 dBu contour is less than 20 kilometers. Even at this short distance, the predicted area of second adjacent channel interference from a LP1000 station is substantial and cannot be ignored.

The measurements show that most clock radios and portables are more susceptible to interference. For example, for clock, personal and portable-style radios the median D/U for second adjacent channel interference is 11.4 dB poorer that the median for all receivers at a

[11] The radii are calculated using the propagation curves of the Commission's rules. The curves are not defined for distances less than 1.5 kilometers. For such short distances, the field strength values are extrapolated by using the

desired signal strength of -65 dBm. At -55 dBm and -45 dBm the performance is 7.0 dB and 3.6 dB worse, respectively.

Predicted interference radii are of course smaller for third-adjacent channel interference than for the cases of second-adjacent channel interference described above. However, even such radii are not negligible. For example, at an 80 dBu desired contour, the interference radius around an LP1000 station for clock, personal and portable radios is 0.73 kilometers. Even considering LP100 stations, the radius is 90 meters. This radius may be small but these stations are likely to locate close to receivers to provide service because the radius of service is small, approximately 5.7 kilometers.

Measured First Adjacent Channel Interference Ratios

Although the Commission has proposed basing LPFM first adjacent channel spacing on the present standard interference ratio, NAB conducted first adjacent channel tests. Table 5 shows measured median first adjacent channel ratios in dB compared with the ratio of the Commission's rules.

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slope for short distances between 1 and 2 kilometers with the constraint that field strength may not exceed that of free space.

Table 5

First Adjacent Channel Interference Ratios (dB)

	Received Power		
FCC Standard	- 65 dBm	- 55 dBm	-45 dBm
6	0.2	2.7	3.0

The measured first adjacent channel ratios are generally in good agreement with the standard ratio used in the rules and show relatively little improvement over the years.

Measured Co-Channel Interference Ratios

Measured median co-channel ratios are greater (approximately 14 dB) than the FCC's specified ratio of 20 dB and are essentially independent of desired received power. This is due primarily to the use of stereo for the desired test signal (and stereo reception for those test receivers so-equipped). Stereo transmission is almost universal for FM stations, even when the stations' program material is monaural. Further, most FM stereo radios and receivers have no stereo-override switch to allow a reduction in potential interference.

One might conclude that present co-channel interference will "mask" new LPFM interference because the required ratio is greater than the standard ratio of the rules. This is generally not the case. The first-adjacent channel separation requirement is so large that the requirement prevents the allocation of co-channel stations on a "lattice" or "grid" at minimum separations. The Commission's staff conducted a study to develop an FM assignment plan based on a lattice.[12] The plan was based on a co-channel ratio of 36 dB for stereo, which agrees well with the NAB measured value of 34 dB. The required first adjacent channel separation from the study is 43 percent of the co-channel distance. In the rules, the percentage is much greater, more than 60 percent for Class A stations and over 80 percent in the case of Class C stations. If a co-channel lattice were packed, then there would be no location to place first adjacent channel stations unless they were a lower class. This situation is not true in the case of television allocations where the required adjacent channel separation is approximately one third of the co-channel requirement and the development of a saturated co-channel lattice is possible.

It is probably too late to increase the co-channel separation for existing FM stations, but it is clear that if LPFM stations are permitted, quality reception would require a spacing based upon a ratio of approximately 34 dB, rather than 20 dB.

Summary of Comparison of Measured and Standard Ratios

The interference ratios forming the basis of the rules were developed based upon measurements taken in the 1940's. As discussed in another MLJ report for NAB's comments, the desired received power for the Commission's measurements is considered to be -55 dBm.[13] Table 6 presents a comparison of the existing FCC ratios with the measured ratios for -55 dBm, and the difference or "improvement."

[12] H.Fine and G. L. Sharp, FCC/OCE RS 75-08, FM Broadcast Channel Frequency Spacing, p. 22.
[13] MLJ report, "Standard of Service for FM Receiver Tests", p 4.

Table 6

Comparison of Measured and Standard Interference Ratios (dB)

Interference Case	FCC Standard	Measured	Improvement
Co-channel	20	33.8	-13.8
1st Adjacent	6	2.7	3.3
2nd Adjacent Reserved	-20	-23.7	3.7
2nd Adjacent Non-reserved	-40	-23.7	-16.3
3rd Adjacent	-40	-32.0	-8.0

Table 6 shows a slight improvement in first adjacent channel interference rejection capability, and second adjacent channel interference rejection capability with regard to the -20 dB reserved band standard. However, it also shows a significant degradation in co-channel, non-reserved band second adjacent channel, and third adjacent channel performance.

Conclusions

The receivers tested are believed to be representative of receivers used by the public at this time. The interference ratios measured in the NAB's receiver test program show that the interference susceptibility of contemporary receivers has generally not improved since the rules were adopted in the 1940's. This is true for the second and third-adjacent channel cases where the Commission is considering ignoring potential interference caused by proposed LPFM stations. In addition, the measurements show that receiver interference rejection performance tends to decline for strong FM signals. Consequently, if LPFM stations were allowed to operate within a station's service contour, they would cause much more interference than predicted by the use of a constant interference ratio that is pertinent at a station's protected contour. For the median receiver, the assumption of constant receiver interference performance regardless of desired field strength is inappropriate.

Available sales data indicate that the receivers most susceptible to second and third adjacent channel interference comprise the majority of receivers in the hands of the public. These classes of receivers, clock, personal and portable-style radios, are more susceptible than the overall population to second and third adjacent channel interference, but are a large proportion (approximately 65 percent) of the FM receiver population. The sales data show that automobile OEM receivers comprise from about 9 to 21 percent of receivers, and thus the interference rejection characteristics of these receivers cannot be used as the primary basis for interference standards.

Data reported to the Commission is presented by type of receiver and hence may be weighted to reflect listening pattern data, if such data becomes available. The measured interference susceptibility results can also be used to predict areas of interference for different types of reception, vehicular for example. The measured results show that contemporary receivers are also more susceptible to co-channel interference than older receivers.

AFFIDAVIT

COUNTY OF ARLINGTON)
) SS:
COMMONWEALTH OF VIRGINIA)

JOSEPH W. STIELPER, being duly sworn upon oath deposes and says:

That he is employed as a Senior Engineer by the firm of JMS Worldwide, Inc. d/b/a MLJ consulting telecommunications engineers;

That this firm has been retained by the National Association of Broadcasters to prepare this engineering statement;

That he has either prepared or directly supervised the preparation of all technical information contained in this engineering statement; and that the facts stated in this engineering statement are true of his knowledge, except as to such statements as are herein stated to be on information and belief, and as to such statements he believes them to be true.

Joseph W. Stielper

Joseph W. Stielper

Subscribed and sworn to before me this 21st day of July, 1999

Jacqueline Marie Richardson

Jacqueline Marie Richardson, Notary Public

My commission expires October 31, 2001.

AFFIDAVIT

COUNTY OF ARLINGTON	)	
	) SS:	
COMMONWEALTH OF VIRGINIA	)	

JOHN C. KEAN, being duly sworn upon oath deposes and says:

That he is employed as a Director of Engineering by the firm of JMS Worldwide, Inc. d/b/a MLJ consulting telecommunications engineers;

That this firm has been retained by the National Association of Broadcasters to prepare this engineering statement;

That he has either prepared or directly supervised the preparation of all technical information contained in this engineering statement; and that the facts stated in this engineering statement are true of his knowledge, except as to such statements as are herein stated to be on information and belief, and as to such statements he believes them to be true.

John C Kean

John C. Kean

Subscribed and sworn to before me this 21st day of July, 1999

Jacqueline Marie Richardson

Jacqueline Marie Richardson, Notary Public

My commission expires October 31, 2001.

Appendix A
Receivers Tested in the NAB Measurement Program
(Page 1 of 2)

A. Clock or Table

Make	Model	Serial Number	Description
Aiwa	FR-A37	S21L18810351	AM/FM Clock Radio
General Electric	7-4852A	None	AM/FM Clock Radio
Philips/Magnavox	AJ3840/17M	KZ009843097244	AM/FM Clock Radio
Sony	ICF-C121	1412093	AM/FM Clock Radio
Zenith	Z212G	2181084	AM/FM/TV Stereo

B. Personal portables

Make	Model	Serial Number	Description
Aiwa	HS-TX386	S08LV8830637	AM/FM
Philips/Magnavox	AQ6688/17C	14446	AM/FM/Cassette
Sony	SRF-49	1188972	AM/FM
Sony	SRF-HM55	555868	AM/FM
Sony	WM-FS191	1249411	AM/FM/Cassette

C. Portable

Make	Model	Serial Number	Description
Emerson	PS6528	90124954LG	AM/FM Stereo/Cassette
Panasonic	RX-CS720	GK8AB38749	Personal Sound System
Radio Shack	12-639A	None	AM/FM Mono
RCA	RP7700	None	AM/FM Mono
Sony	CDF-Z110	1439435	Personal Sound System

D. Component

Make	Model	Serial Number	Description
JVC	RX-554VBK	13X0299	AM/FM Stereo Receiver
Kenwood	VR-205	8110029	AM/FM Stereo Receiver
Pioneer	VSX-D557	SIDI018717US	AM/FM Stereo Receiver
Sharp	MD-X5	70800324	AM/FM with Mini Disk
Sony	STR-DE525	8831310	AM/FM Stereo Receiver

Appendix A
Receivers Tested in the NAB Measurement Program
(Page 2 of 2)

D. Auto After-market

Make	Model	Serial Number	Description
Blaupunkt	MESA CR67	BP7413W2785625	Car Stereo
Jensen	XCC5220	ORR002326	Car Stereo
JVC	KS-RX177	113H2496	Car Stereo
Kenwood	KDC-S5009	80405408	Car Stereo
Pioneer	DEH-1000	TATM013945UC	Car Stereo

E. Auto OEM

Make	Model	Serial Number	Description
Chrysler	PO485861AD	None	Car Stereo
Delco	16232113	2131	Car Stereo
Ford	F87F-19B132-AB	None	Car Stereo

Appendix B

Median Desired to Undesired Signal Ratios as a Function of Received Power

Figure 1 - Second Adjacent Channel Data - All Receivers

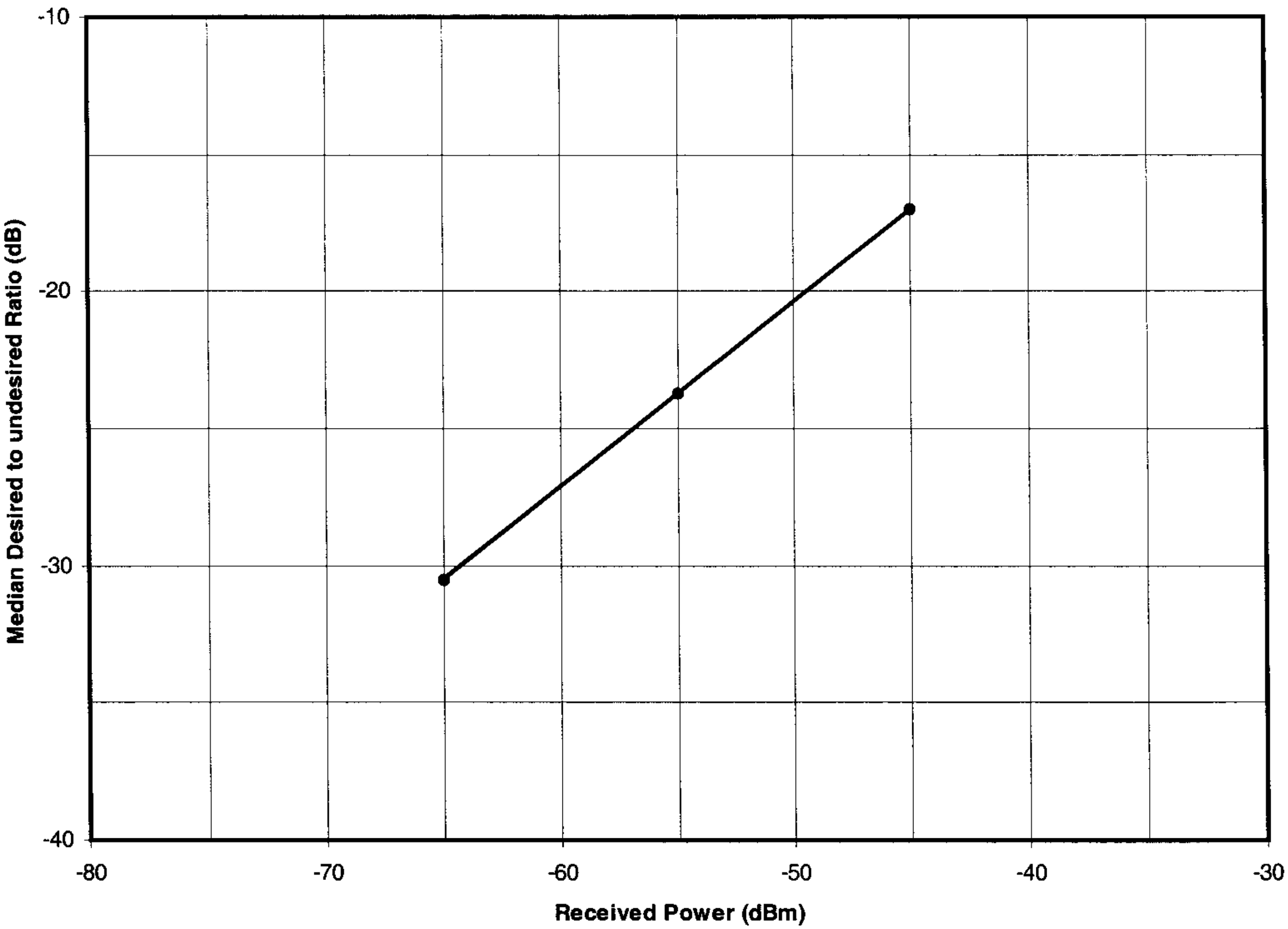

Figure 2 - Third Adjacent Channel Data - All Receivers